



Review

Recent advances in bioactive polysaccharides from *Lycium barbarum* L., *Zizyphus jujuba* Mill, *Plantago* spp., and *Morus* spp.: Structures and functionalities



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ARTICLE INFO

Article history:

Received 27 December 2015

Received in revised form

18 March 2016

Accepted 23 March 2016

Available online 25 March 2016

Keywords:

Polysaccharide

Structure

Physicochemical properties

Biological activities

Application

Challenges

ABSTRACT

Recently, a great deal of interest has been paid to polysaccharides isolated from natural sources due to their various beneficial health effects. Many of these special interested polysaccharides have a long history as part of herbal formulas that have been widely accepted in Asian countries. *Lycium barbarum* L. (*L. barbarum*), *Zizyphus jujuba* Mill (*Z. jujuba*), *Plantago* spp., and *Morus* spp. have been widely used in China as traditional herbal medicines and functional foods for millennia. Polysaccharides are bioactive constituents of these plants and are of interest because of their functional properties, which include immunomodulatory, antioxidant, antitumor, and hypoglycemic activity. This paper provides an overview of recent advances in understanding of the physicochemical, structural features and biological effects of these bioactive polysaccharides from *L. barbarum*, *Z. jujuba*, *Plantago* spp., and *Morus* spp. This review is to provide background and useful updated information for future research and application of these polysaccharides.

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1. Introduction

Recently, polysaccharides derived from natural resources have attracted extensive attention owing to their non-cytotoxic properties and to a variety of beneficial pharmacological effects that have been demonstrated for these compounds (Xie et al., 2016). It is also noticed that this trend has become more and more significant which could be evidenced by the number of papers published during the last 5 years in this field (Xie, Jin, et al., 2015). Many of these special polysaccharides have been using as part of herbal remedies for a very long history and have been accepted around the world. These natural polysaccharides are relatively common, and they have tremendous structural diversities and diverse biological properties. Numerous studies come to the viewpoint that polysaccharides have many types of biological activities, such as antioxidant (Chang, Hsu, & Chen, 2010; Wang, Zhao, Andrae-Marobela, Okatch, & Xiao, 2013; Wang, Xie, et al., 2015; Wang, Ju, et al., 2015; Wang, Xie, et al., 2016; Xie et al., 2010; Xie, Liu et al., 2013; Xie, Zhang et al., 2015), immunomodulatory (Huang, Tang, et al., 2009; Wasser, 2002), antidiabetic (Xu et al., 2015), antibiotic (Chin, Chang, Tseng, & Chen, 2014), antimicrobial (Xie et al., 2012) and anti-inflammatory activities (Al-Reza, Yoon, Kim, Kim, & Kang, 2010; Liu & Lin, 2012). *Lycium barbarum* L. (*L. barbarum*), known as Goji berry or wolfberry, belongs to genus *Lycium* of the family Solanaceae, is a well-known traditional Chinese medicine and tonic food for thousands of years. It is widely distributed in arid and semi-arid regions of China, Korea, Japan, Europe, North America and the Mediterranean areas. Nowadays, *L. barbarum* are being used not only in China but also worldwide, especially in Korea, Japan, and Europe, where it is taken as popular nutraceutical foods or health dietary supplements in various forms such as soups, juice, wine, tea and a variety of solid foods (Amagase & Farnsworth, 2011). It has been suggested that eating or drinking products made from *L. barbarum* can protect eyesight, lower blood lipid levels, eliminate phlegm, counteract fatigue, promote fertility, enhance immunity, and prevent diseases including hepatitis, diabetes, and hyperlipidemia. *Zizyphus jujuba* Mill. (*Z. jujuba*), commonly known as jujube, belonging to the plant family Rhamnaceae, is indigenous in China and consumed as a traditional and functional food worldwide. It is widely distributed in Southeast Asia, North America, Africa, Australia and Europe in tropical and subtropical regions. As a Chinese medicinal herb, *Z. jujuba* is used as digestion improvement, antianemic, palliative (Sun, Liang, Shan, Viernstein, & Unger, 2011) and antitumor in China for thousands

of years. This plant also possesses various human health-promoting effects, such as antioxidant (Sun et al., 2011; Wang, Huang, et al., 2016), anti-cancer (Huang et al., 2007), liver protective (Ghaly, Said, & Abdel-Wahhab, 2008), anti-inflammatory (Al-Reza et al., 2010), hypoglycemic (Shirdel, Maadani, & Mirbadalzadeh, 2009), anti-diabetic, immune-enhancing and sedative and hypnotic (Anand, Singh, Grand, Chandan, & Gupta, 1989) activities. *Plantago* spp., belong to the *Plantaginaceae* family, arevaluable medicinal herbs that are widely distributed in China, Pakistan, Russia, Korea, India and North America. *Plantago* spp. have been widely used in Chinese folk medicine as anti-inflammatory, antimicrobial and antitumor agents (Beara et al., 2012). Nowadays, *Plantago* spp. are being used as popular functional foods or dietary supplements all over the world. *Morus* spp. are a well-known deciduous trees widely distributed around the world, belonging to the genus of *Morus* of *Moraceae* family. As a traditional Chinese medicine, its leaves, twigs, roots (bark) and fruits are widely used for the treatment of cough, hydroncus, constipation, hyperlipemia, hyperglycaemia, and hypertension in China for 7000 years (Butt, Nazir, Sultan, & Schroën, 2008). *Morus* spp. fruits are eaten raw or processed into juice, wine, and jam, and the leaves have been widely used to produce a variety of functional foods (Thirugnanasambandham, Sivakumar, & Maran, 2015). Phytochemical investigations have indicated that *L. barbarum*, *Z. jujuba*, *Plantago* spp., *Morus* spp. contain many active constituents, such as flavonoids, protein, polysaccharides, phenolics, alkaloids, and steroids. Among them, polysaccharides are considered as one of the most important components. Modern scientific research and experiments have proved that polysaccharides are the main bioactive constituents in *L. barbarum* (Ke et al., 2011). It is well known that the biological functions of polysaccharides are intimately related to their structural features (Xie, Jin, et al., 2015; Yuan et al., 2015). Xie, Shen, et al. (2013) and Xie et al. (2014) showed that polysaccharides are diverse in their molecular weight (*M_w*), monosaccharide composition, and in the configuration and position of their glycosidic linkages. Many chemical properties and structural features of polysaccharides from *L. barbarum*, *Z. jujuba*, *Plantago* spp., and *Morus* spp. had been demonstrated in recent years, mainly *M_w*, monosaccharide compositions and rheological properties (Al-Assaf et al., 2003; Van Craeyveld, Delcour, & Courtin, 2009; Yin, Lin, et al., 2012; Yin et al., 2015).

This paper will provide an overview of recent advances in understanding of the structures and functions of these groups of polysaccharides. The first group that will be examined are those

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